

DESCRIPTION

SEMIFINISHED FLAT TUBE, PROCESS FOR PRODUCING SAME, FLAT TUBE,
HEAT EXCHANGER COMPRISING THE FLAT TUBE AND PROCESS FOR
FABRICATING THE HEAT EXCHANGER

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CROSS REFERENCE TO RELATED APPLICATIONS

This application is an application filed under 35 U.S.C.
§111(a) claiming the benefit pursuant to 35 U.S.C. §119(e) (1)
of the filing data of Provisional Application No. 60/428,922
10 filed November 26, 2002 pursuant to 35 U.S.C. §111(b).

TECHNICAL FIELD

The present invention relates to semifinished flat tubes
useful for producing flat tubes for use as heat exchange tubes
15 for heat exchangers, such as refrigerant tubes in condensers
or evaporators for motor vehicle air conditioners, oil tubes
for motor vehicle oil coolers, water tubes for motor vehicle
radiators and heat medium tubes for heater cores, a process
for producing the same, flat tubes, heat exchangers comprising
20 such flat tubes and a process for fabricating the exchanger.

The term "aluminum" as used herein and in the appended
claims includes aluminum alloys in addition to pure aluminum.

BACKGROUND ART

25 In recent years, widely used in motor vehicle air
conditioners in place of conventional serpentine condensers
are condensers which comprise, as shown in FIG. 15, a pair
of headers 100, 101 arranged in parallel and spaced apart from

each other, parallel flat refrigerant tubes 102 made of aluminum and each joined at its opposite ends to the two headers 100, 101, corrugated aluminum fins 103 each disposed in an air flow clearance between the adjacent refrigerant tubes 102 and brazed to the adjacent tubes 102, an inlet pipe 104 connected to the upper end of peripheral wall of the first 100 of the headers, an outlet pipe 105 connected to the lower end of peripheral wall of the second 101 of the headers, a first partition 106 provided inside the first header 100 and positioned above the midportion thereof, and a second partition 107 provided inside the second header 101 and positioned below the midportion thereof, the number of refrigerant tubes 102 between the inlet pipe 104 and the first partition 106, the number of refrigerant tubes 102 between the first partition 106 and the second partition 107 and the number of refrigerant tubes 102 between the second partition 107 and the outlet pipe 105 decreasing from above downward to provide groups of channels. A refrigerant flowing into the inlet pipe 104 in a vapor phase flows zigzag through units of channel groups in the condenser before flowing out from the outlet pipe 105 in a liquid phase. The condensers of the construction described are called multiflow condensers, and realize high efficiencies, lower pressure losses and supercompactness.

It is required that the refrigerant tube 102 of the condenser described be excellent in heat exchange efficiency and have pressure resistance to the high-pressure gaseous refrigerant to be introduced thereinto. Moreover, the tube needs to be small in wall thickness and low in height so as

to make the condenser compact.

The publication of Japanese Patent No. 2915660 discloses a known flat tube which is excellent in heat exchange efficiency for use as such a refrigerant tube 102. The flat tube disclosed in the above publication comprises an upper wall, a lower wall, a right and a left side wall interconnecting the upper and lower walls at the respective right and left side edges thereof, and a plurality of reinforcing walls interconnecting the upper and lower walls, extending longitudinally of the tube and spaced apart from one another as positioned between the right and left side walls, the tube having parallel fluid channels formed inside thereof. Each of the reinforcing walls is provided by forming a ridge projecting inward from at least one of the upper and lower walls integrally therewith and brazing the ridge to the inner surface of the other wall which is flat. Alternatively, the reinforcing wall is provided by forming a downward ridge projecting downward from the upper wall integrally therewith, forming an upward ridge projecting upward from the lower wall integrally therewith and brazing the ridges to each other end to end.

Such a flat tube is fabricated from a metal plate having two first portions for making the upper and lower walls, a second portion interconnecting the first portions, and two projecting third portions formed on the respective first portions integrally therewith each at a side edge thereof opposite to the second portion, by a process including bending the metal plate to the shape of a hairpin at the second portion and brazing the third portions to each other end to end. In

the case where the reinforcing walls are to be made by the first-mentioned method, the ridges formed on at least one of the first portions are brazed to the other first portion simultaneously when the third portions are brazed to each other.

5 In the case where the reinforcing walls are to be made by the second-mentioned method, the ridges formed on one of the first portions and the ridges formed on the other first portion are brazed simultaneously when the third portions are brazed to each other.

10 Such flat tubes are produced in the following manner simultaneously when a condenser is fabricated. A condenser and flat tubes are fabricated at the same time by bending an aluminum plate having two first portions for making the upper and lower walls, a second portion interconnecting the first
15 portions, and two projecting third portions formed on the respective first portions integrally therewith each at a side edge thereof opposite to the second portion, to the shape of a hairpin at the second portion by the roll forming process to cause the third portions to butt against each other and
20 to make a semifinished continuous body, thereafter cutting the continuous body into predetermined lengths to prepare a plurality of semifinished flat tubes, preparing a pair of aluminum headers each having semifinished flat tube inserting holes equal in number to the number of the semifinished flat
25 tubes and arranged at a spacing and a plurality of corrugated aluminum fins, arranging the pair of headers as spaced apart and arranging the semifinished flat tubes and the corrugated fins alternately, inserting opposite ends of the semifinished

flat tubes into the respective holes of the headers, and simultaneously brazing the third portions of each of the semifinished flat tubes to each other, the flat tubes to the headers and the flat tubes to the corrugated fins.

5 However, we have found that the semifinished flat tube has the following problems. When the semifinished continuous body is cut into semifinished flat tubes, opposite ends of the flat tube open to entail the likelihood that the tube opposite ends can not be inserted into the corresponding holes
10 of the headers in fabricating the condenser. The aluminum plate for use in making the semifinished flat tubes is given a reduced thickness recently to obtain a condenser of reduced weight, with the result the semifinished flat tubes are insufficient in rigidity. This results in the likelihood that
15 the tubes will deform when the tubes are assembled into a condenser or otherwise handled.

 An object of the present invention is to resolve the above problems and to provide a semifinished flat tube which can be prevented from opening at its opposite ends and which has
20 higher rigidity than those of the prior art.

DISCLOSURE OF THE INVENTION

 The present invention provides a first semifinished flat tube comprising a pair of flat walls opposed to each other,
25 and two side walls interconnecting the flat walls at opposite side edges thereof for use in producing a flat tube, the semifinished flat tube being produced from a metal plate having two first portions for making the flat walls, a second portion

interconnecting the first portions for forming one of the side walls, and two third portions projecting from the respective first portions and each formed on the first portion at a side edge thereof opposite to the second portion for making the
5 other side wall, by bending the metal plate to the shape of a hairpin at the second portion to cause the third portions to butt against each other and welding the two third portions to each other at least at longitudinal opposite end portions thereof from outside.

10 With the first semifinished flat tube of the invention, the two third portions are welded to each other at least at longitudinal opposite end portions thereof from outside. This prevents the semifinished flat tube from opening at its opposite ends, and the opposite ends of the tubes to be used for
15 fabricating a heat exchanger can be reliably inserted into the respective tube inserting holes of the headers. Further the third portions of each of the semifinished tubes can be brazed subsequently in the fabrication process without producing any fault. Moreover, the semifinished tube of the
20 invention has higher rigidity than those of the prior art, and such tubes can be assembled into the heat exchanger or otherwise handled free of deformation.

In the first semifinished flat tube of the invention, the two third portions may be joined to each other by laser
25 welding. In this case, the third portions can be welded to each other from outside relatively easily.

In the first semifinished flat tube of the invention, the third portions of the metal plate may protrude from and

be made integral with the respective first portions.

Alternatively, the third portions of the metal plate may each be formed by bending a side edge portion of the first portion.

In the first semifinished flat tube of the invention,
5 the two third portions may be welded to each other intermittently at a spacing longitudinally thereof. This gives higher rigidity to the semifinished flat tube than conventionally, and such tubes can be prevented from deforming when to be assembled into a heat exchanger or otherwise handled.

10 With the first semifinished flat tube wherein the third portions are welded to each other intermittently, the weld positioned at each of opposite end portions may be at a distance of up to 10 mm from the longitudinal end of the third portion. This prevents the opposite ends of the semifinished tube from
15 opening with improved effectiveness.

With the first semifinished flat tube wherein the third portions are welded to each other intermittently, the weld positioned at each of opposite end portions may be at a distance of up to 5 mm from the longitudinal end of the third portion.
20 This prevents the opposite ends of the semifinished tube from opening with further improved effectiveness.

With the first semifinished flat tube wherein the third portions are welded to each other intermittently, the pitch P of all the welds may be up to 100 mm. The semifinished tube
25 is then reliably given higher rigidity than in the prior art, and such tubes can be prevented from deforming reliably when to be assembled into a heat exchanger or otherwise handled.

With the first semifinished flat tube wherein the third

portions are welded to each other intermittently, it is assumed that the welds have a nugget diameter D and that the two third portions have a combined height H . The ratio D/H may then be at least 0.18. Further assuming that the welds have a depth of penetration d and that each of the third portions has a thickness t , d/t may be at least 0.25. In these cases, the welds can be prevented from cracking. This eliminates the likelihood that the brazing operation subsequently conducted will produce a faulty brazed joint.

10 With the first semifinished flat tube of the invention, the two third portions may be welded to each other continuously over the entire length thereof. The tube is then given higher rigidity than the first semifinished tube wherein the third portions are welded to each other intermittently, and such tubes are reliably prevented from deforming when to be assembled into a heat exchanger or to be otherwise handled. However, the semifinished tube wherein the third portions are welded to each other intermittently can be produced at a higher speed than the one where the third portions are welded continuously.

15 With the first semifinished flat tube wherein the third portions are welded to each other continuously, it is assumed that the continuous weld has a width W and that the two third portions have a combined height H . The ratio W/H may then be at least 0.18. Further assuming that the weld has a depth of penetration d and that each of the third portions has a thickness t , d/t may be at least 0.25. In these cases, the weld can be prevented from cracking. This eliminates the likelihood that the brazing operation subsequently conducted

will produce a faulty brazed joint.

With the first semifinished flat tube of the invention, the metal plate may comprise an aluminum brazing sheet, with a brazing material layer formed at the top end of each of the
5 third portions. When the third portions are to be brazed to each other subsequently, the brazing material layer at the top ends is usable for brazing, consequently eliminating the time and labor needed for applying a brazing material separately.

The present invention provides a second semifinished flat
10 tube comprising a pair of flat walls opposed to each other, and two side walls interconnecting the flat walls at opposite side edges thereof for use in producing a flat tube, the semifinished flat tube being produced from a metal plate having a first portion for making one of the flat walls, two second
15 portions having an approximately one-half the width of the first portion for making the other flat wall, two third portions connecting the first portion to the respective two second portions, and two fourth portions extending upright from the respective second portions and each formed on the second portion
20 at a side edge thereof opposite to the third portion, by bending the metal plate at the third portions to cause the side edges to butt against each other, with top ends of the two fourth portions in bearing contact with the first portion and welding the two second portions to each other at least at longitudinal
25 opposite end portions thereof from outside.

With the second semifinished flat tube of the invention, the two second portions are welded to each other at least at longitudinal opposite end portions thereof from outside. This

prevents the semifinished flat tube from opening at its opposite ends. When such tubes are to be used for fabricating a heat exchanger, the tube opposite ends can be reliably inserted into the respective tube inserting holes of the headers.

- 5 Further the fourth portions of each of the semifinished tubes can be brazed subsequently in the fabrication process without producing any fault. Moreover, the semifinished tube of the invention has higher rigidity than those of the prior art. When to be assembled into the heat exchanger or otherwise
10 handled, such tubes can be prevented from deforming.

In the second semifinished flat tube of the invention, the two second portions may be joined to each other by laser welding. In this case, the second portions can be welded to each other from outside relatively easily.

- 15 With the second semifinished flat tube of the invention, the two second portions may be welded to each other intermittently at a spacing longitudinally thereof. Alternatively, the two second portions may be welded to each other continuously over the entire length thereof. In these
20 cases, the semifinished tube is given higher rigidity than conventionally, and when to be assembled into a heat exchanger or otherwise handled, such tubes can be prevented from deforming.

- With the second semifinished flat tube of the invention,
25 the metal plate may comprise an aluminum brazing sheet having a brazing material layer over opposite surfaces thereof. When the second portions, as well as the fourth portions, are to be subsequently brazed, the brazing material layer of the metal

plate is usable for brazing. This eliminates the time and labor needed for applying a brazing material separately.

The present invention provides a process for producing a semifinished flat tube comprising a pair of flat walls opposed to each other, and two side walls interconnecting the flat walls at opposite side edges thereof for use in producing a flat tube, the process being characterized by preparing a metal plate having two first portions for making the flat walls, a second portion interconnecting the first portions for forming one of the side walls, and two third portions projecting from the respective first portions and each formed on the first portion at a side edge thereof opposite to the second portion for making the other side wall, bending the metal plate by the roll forming process to the shape of a hairpin at the second portion to cause the third portions to butt against each other, welding the two third portions to each other intermittently at a spacing longitudinally thereof from outside to make a semifinished continuous body and thereafter cutting the semifinished continuous body into semifinished flat tubes each having a weld at each of longitudinal opposite end portions thereof.

The present invention provides another process for producing a semifinished flat tube comprising a pair of flat walls opposed to each other, and two side walls interconnecting the flat walls at opposite side edges thereof for use in producing a flat tube, the process being characterized by preparing a metal plate having two first portions for making the flat walls, a second portion interconnecting the first portions for forming

one of the side walls, and two third portions projecting from the respective first portions and each formed on the first portion at a side edge thereof opposite to the second portion for making the other side wall, bending the metal plate by
5 the roll forming process to the shape of a hairpin at the second portion to cause the third portions to butt against each other, welding the two third portions to each other continuously over the entire length thereof from outside to make a semifinished continuous body and thereafter cutting the semifinished
10 continuous body.

With these processes for producing a semifinished flat tube, the two third portions are preferably joined to each other from outside by laser welding.

The present invention provides an apparatus for producing
15 a semifinished flat tube comprising a pair of flat walls opposed to each other, and two side walls interconnecting the flat walls at opposite side edges thereof for use in producing a flat tube, the apparatus comprising a roll forming device for bending a metal plate having two first portions for making
20 the flat walls, a second portion interconnecting the first portions for forming one of the side walls, and two third portions projecting from the respective first portions and each formed on the first portion at a side edge thereof opposite to the second portion for making the other side wall, to the shape
25 of a hairpin at the second portion to cause the third portions to butt against each other, a welding device disposed downstream from the roll forming device for welding the two third portions to each other from outside and a cutting device

disposed downstream from the welding device.

With the apparatus of the invention for producing a semifinished flat tube, the welding device is preferably a laser welding device.

5 The present invention provides a flat tube which comprises the first semifinished flat tube described above wherein the two third portions are brazed to each other. In this case, the two third portions are brazed to each other as temporarily held together by the welds at least at respective opposite
10 end portions, so that the brazed portions are free of faults over the entire length thereof.

 The present invention provides a heat exchanger comprising a pair of headers arranged in parallel and spaced apart from each other, a plurality of parallel heat exchange
15 tubes each comprising the flat tube described above and each joined at opposite ends thereof to the two headers, fins each disposed in an air flow clearance between each pair of adjacent heat exchange tubes and brazed to the adjacent tubes.

 The present invention provides a process for fabricating
20 a heat exchanger characterized by preparing a plurality of semifinished flat tubes described above, preparing a pair of headers each having semifinished tube inserting holes equal in number to the number of semifinished flat tubes and formed at a spacing and a plurality of fins, arranging the pair of
25 headers as spaced apart and arranging the semifinished flat tubes and the fins alternately, inserting opposite ends of the semifinished flat tubes into the respective tube inserting holes of the headers, and brazing the two third portions of

each of the semifinished flat tubes to each other, the semifinished flat tubes to the headers, and each of the fins to the adjacent semifinished flat tubes on opposite sides thereof at the same time.

5 The present invention provides a vehicle comprising a refrigeration cycle having a compressor, a condenser and an evaporator, the condenser being the heat exchanger described above.

BRIEF DESCRIPTION OF THE DRAWINGS

10 FIG. 1 is a cross sectional view showing a flat tube produced from a first embodiment of semifinished flat tube shown in FIGS. 4 to 6. FIG. 2 is a diagram schematically showing an apparatus for fabricating the first embodiment of semifinished flat tube. FIG. 3 includes views showing some
15 steps of a process for fabricating the first embodiment of the semifinished flat tube. FIG. 4 is a perspective view partly broken away and showing the first embodiment of semifinished flat tube. FIG. 5 is a fragmentary plan view showing the first embodiment of the semifinished flat tube. FIG. 6 is an enlarged
20 view in section taken along the line VI-VI in FIG. 5. FIG. 7 is a perspective view partly broken away and showing a second embodiment of semifinished flat tube. FIG. 8 is a cross sectional view showing a flat tube produced from a third embodiment of semifinished flat tube shown in FIG. 10. FIG.
25 9 includes views showing some steps of a process for fabricating the third embodiment of the semifinished flat tube. FIG. 10 is a perspective view partly broken away and showing the third embodiment of semifinished flat tube. FIG. 11 is a perspective

view partly broken away and showing a fourth embodiment of semifinished flat tube. FIG. 12 is a cross sectional view showing a flat tube produced from a fifth embodiment of semifinished flat tube shown in FIG. 10. FIG. 13 includes
5 views showing some steps of a process for fabricating the fifth embodiment of the semifinished flat tube. FIG. 14 is a perspective view partly broken away and showing a fifth embodiment of semifinished flat tube. FIG. 15 is a perspective view showing a condenser for use in a motor vehicle air
10 conditioner.

BEST MODE OF CARRYING OUT THE INVENTION

Embodiments of the present invention will be described below with reference to the drawings. In the following
15 description, the upper and lower sides, and the left- and right-hand sides of FIGS. 1, 8 and 12 will be referred to as "upper," "lower," "left" and "right," respectively. Throughout the drawings, like parts will be designated by like reference numerals.

20 FIG. 1 shows a flat tube, FIG. 2 shows an apparatus for producing semifinished flat tubes, FIG. 3 shows some steps of a process for producing the semifinished flat tube, and FIGS. 4 to 6 show the semifinished flat tube.

With reference to FIG. 1, the flat tube 1 is made of
25 aluminum and comprises an upper and a lower flat wall 2, 3 (a pair of flat walls) opposed to each other, left and right opposite side walls 4, 5 interconnecting the upper and lower walls 2, 3 at left and right opposite side edges thereof, and

a plurality of reinforcing walls 6 interconnecting the upper and lower walls 2, 3, extending longitudinally of the tube and spaced apart from one another as positioned between the right and left side walls 4, 5, the tube having parallel fluid channels 7 formed inside thereof. Although not shown, each of the reinforcing walls 7 is provided with communication holes for causing the adjacent fluid channels 7 to communicate with each other therethrough, the communication holes in the entire tube being in a staggered arrangement when seen from above.

10 The left side wall 4 comprises a portion 9 projecting downward from the left side edge of the upper wall 2 integrally therewith and a portion 10 projecting upward from the left side edge of the lower wall 3 integrally therewith, and is formed by causing these portions 9, 10 to butt against each other and brazing these portions in this state. The right side wall 5 is made integral with the upper and lower walls 2, 3.

Each of the reinforcing walls 6 comprises a downward ridge 11 projecting downward from the upper wall 2 integrally therewith and an upward ridge 12 projecting upward from the lower wall 3 integrally therewith, and is formed by causing these ridges 11, 12 to butt against each other and brazing the ridges 11, 12 in this state.

25 The flat tube 1 is produced by making a semifinished flat tube first, and brazing the semifinished flat tube at the required portions.

The semifinished flat tube is produced by the process to be described below using a production apparatus shown in

FIG. 2.

First, an aluminum brazing sheet clad with a brazing material over opposite surfaces thereof is passed between rolling rolls to prepare a metal plate 15 as shown in FIG. 3(a) for making flat tubes. The metal plate 15 comprises two flat first portions 17, 18 for making the upper and lower walls 2, 3, a second portion 16 interconnecting the two first portions 17, 18 integrally for forming the right side wall 5, two third portions 9, 10 projecting upward from the respective first portions 17, 18 integrally with the first portion each at a side edge thereof opposite to the second portion 16 for making the left side wall 4, and ridges 11, 12 projecting upward from the respective first portions 17, 18 integrally therewith and arranged at a predetermining spacing leftward or rightward. The ridges 11 on one of the first portions, 17, and the ridges 12 on the other first portion 18 are positioned symmetrically about a center line with respect to the widthwise direction. The second portion 16 has a larger thickness than the two first portions 17, 18. Further the two third portions 9, 10 have a larger thickness than the ridges 11, 12. The height of the projecting third portions 9, 10 is approximately one-half the width of the second portion 16. By forming the third portions 9, 10 and the ridges 11, 12 on one surface of the aluminum brazing sheet integrally therewith which sheet is clad with the brazing material over opposite surfaces thereof, a brazing material layer (not shown) is formed on opposite side faces and the top faces of the third portions 9, 10 and the ridges 11, 12 and on the upper and lower surfaces of the two first

portions 17, 18. The brazing material layer on the top faces of the third portions 9, 10 and the ridges 11, 12 has a larger thickness than the brazing material layer on the other portions. The third portion 10 on the first portion 18 for making the lower wall 3 is integrally provided, on the top face thereof, with a ridge 19 extending longitudinally of the third portion 10. On the other hand, the third portion 9 on the first portion 17 for making the upper wall 2 has formed in its top face a groove 20 extending longitudinally of the third portion 9 for the ridge 19 to be forced in by a press fit. The ridge 19 and the groove 20 are formed when the aluminum brazing sheet is formed by rolling, and a brazing material layer is present on the top face and opposite side faces of the ridge 19 and on the bottom face and opposite side faces which define the groove 20. The metal plate 15 is prepared in the form of a coil with the third portions 9, 10 and ridges 11, 12 facing radially inward.

The production apparatus shown in FIG. 2 comprises a supply roll 21 for placing the coil 15A of metal plate 15 thereon, a straightening device 22 for correcting the distortion of the metal plate 15 paid out from the roll 21, a roll forming device 23 disposed downstream from the straightening device 22 for bending the metal plate 15 at the second portion 16 to the shape of a hairpin to cause the two third portions 9, 10, as well as the opposed ridges 11, 12 in each pair, to butt against each other, a laser welding device 25 disposed downstream from the roll forming device 23 for joining the butting third portions 9, 10 to each other by laser welding

from outside to make a semifinished continuous body 24, a
straightening device 26 disposed downstream from the welding
device 25 for correcting the distortion of the continuous
body 24, and a cutting device 27 disposed downstream from the
5 correcting device 26 for cutting the continuous body 24.

To produce the semifinished flat tube using the production
apparatus described, the metal plate 15 paid out from the coil
15A on the supply roll 21 is treated by the straightening
device 22 for the removal of distortion, and thereafter fed
10 to the roll forming device 23, by which the metal plate 15
is progressively bent at opposite side edges of the second
portion 16 by the roll forming process [see FIG. 3, (b), (c)]
and finally bent to the shape of a hairpin to cause the two
third portions 9, 10, as well as the ridges 11, 12 in each
15 pair, to butt against each other and to force the ridge 19
into the groove 20 by a press fit, whereby a bent body 28 is
obtained [see FIG. 3, (d)]. At this time, the right side wall
5 is formed by the second portion 16, the upper wall 2 by the
first portion 17 and the lower wall 3 by the other first portion
20 18.

The bent body 28 is then fed to the laser welding device
25, by which the butting parts of the two third portions 9,
10 are joined by laser welding intermittently at a spacing
along the length thereof from outside to make a semifinished
25 continuous body 24. Subsequently, the semifinished continuous
body 24 has its distortion corrected by the straightening
device 26 and is thereafter cut into semifinished flat tubes
each having two welds 31 respectively at longitudinal opposite

end portions of the third portions 9, 10. FIGS. 4 to 6 show the semifinished flat tube 30 thus produced.

As shown in FIGS. 4 to 6, the semifinished flat tube 30 is obtained by intermittently welding the two third portions 9, 10 to each other at the butting ends thereof at a spacing longitudinally of these portions by laser welding, and has a plurality of laser welds 31 formed at a spacing along the longitudinal direction. It is desired that the laser weld 31 and positioned at each of opposite end portions be at a distance L of up to 10 mm, preferably up to 5 mm, from the longitudinal end of the third portion 9 or 10. It is also desired that the pitch P of all the laser welds 31 be up to 100 mm, preferably up to 60 mm, more preferably up to 30 mm.

Assuming that the laser welds 31 have a nugget diameter D and that the two third portions 9, 10 have a combined height H, D/H is preferably at least 0.18. Further assuming that the laser welds 31 have a depth of penetration d and that each of the third portions 9, 10 has a thickness t, d/t is preferably at least 0.25.

A flat tube is produced from the semifinished flat tube 30 by heating the tube 30 at a predetermined temperature to braze the two third portions 9, 10, as well as the correspond ridges 11, 12 in each pair, to each other utilizing the brazing material layer on the metal plate 15, whereby the left side wall 4 and each reinforcing wall 6 are formed. Thus, the flat tube 1 is produced.

When the flat tube 1 is to be used, for example, as the refrigerant tube 102 of the condenser shown in FIG. 15, such

a depth of penetration d and that each of the third portions 9, 10 has a thickness t , d/t is preferably at least 0.25.

With the exception of these features, the flat tube 40 is the same as the semifinished flat tube 30 shown in FIGS. 4 to 6.

5 The semifinished flat tube 40 is produced by a process similar to the process for producing the flat tube 30 shown in FIGS. 4 to 6, using the apparatus shown in FIG. 2. However, the process differs from the process for the tube 30 in that the two third portions 9, 10 are welded by the laser welding
10 device 25 to each other continuously over the entire length thereof from outside.

 The heat exchanger comprising flat tubes which are produced from semifinished flat tubes of either one of the two types described is used in vehicles comprising a refrigeration cycle
15 having a compressor, a condenser and an evaporator, as the condenser of the refrigeration cycle. Alternatively, the heat exchanger is used as the evaporator of the refrigeration cycle. Further alternatively, the heat exchanger may be installed in motor vehicles to serve as an oil cooler or radiator.

20 The present invention will be described below with reference to specific examples.

Example 1

 An aluminum brazing sheet made from JIS BAS211P was rolled into a metal plate 15 shown in FIG. 3, (a). The metal plate
25 was then made into a semifinished flat tube 40 wherein two third portions 9, 10 were continuously joined to each other over the entire length thereof by laser welding as shown in FIG. 7. The laser welding conditions were: pulse width, 0.5

flat tubes 1 may be produced simultaneously with the fabrication of the condenser. More specifically, the condenser is fabricated in the following manner. First prepared are a plurality of semifinished flat tubes 30. Also prepared are a pair of aluminum headers 100, 101 each having semifinished tube inserting holes equal in number to the number of semifinished flat tubes 30, and a plurality of corrugated aluminum fins 103. The pair of headers 100, 101 are then arranged as spaced apart, the semifinished flat tubes 30 and the fins 103 are arranged alternately, and opposite ends of the semifinished flat tubes 30 are inserted into the respective tube inserting holes of the headers 100, 101. The resulting assembly is thereafter heated at a predetermined temperature to braze the two third portions 9, 10, as well as the corresponding ridges 11, 12 in each pair, of each semifinished flat tube to each other, the flat tubes 30 to the headers 100, 101, and each of the corrugated fins 103 to the adjacent flat tubes 30 on opposite sides thereof at the same time utilizing the brazing material layer of the metal plate 15. In this way, the condenser is fabricated.

FIG. 7 shows a second embodiment of semifinished flat tube for use in producing the flat tube of FIG. 1.

The semifinished flat tube 40 shown in FIG. 7 has two third portions 9, 10 which are continuously welded by laser welding over the entire length thereof. Suppose the continuous laser weld 41 has a width W , and the two third portions 9, 10 have a combined height H . The ratio W/H is then preferably at least 0.18. Further assuming that the laser weld 41 has

ms; frequency, 66.7 Hz; pulse energy, 3 J; assist gas, none; work moving velocity, 30 m/min. The continuous laser weld 41 was 0.6 mm in width W and 0.2 mm in the depth of penetration d. The semifinished flat tube 40 was 1.1 mm in the combined height H of the two third portions 9, 10, 0.4 mm in the thickness t of each of the third portions 9, 10, and 16 mm in the overall width.

Examples 2-9

An aluminum brazing sheet made from JIS BAS211P was rolled into a metal plate 15 shown in FIG. 3, (a). The metal plate was then made into a semifinished flat tube 30 wherein two third portions 9, 10 were intermittently joined to each other at a spacing longitudinally thereof by laser welding as shown in FIGS. 4 to 6. The laser welding conditions were: pulse width, 0.5 ms; frequency, 66.7 Hz; pulse energy, 3 J; assist gas, none; work moving velocity, 200 m/min. The laser welds were 0.6 mm in nugget diameter D and 0.2 mm in the depth of penetration d. The weld laser 31 positioned at each of opposite end portions of the third portions 9, 10 was at a distance L of 15 mm from the longitudinal end of the third portion. The tubes 30 of the examples were produced with varying weld pitches P. The semifinished flat tubes 30 were 1.1 mm in the combined height H of the two third portions 9, 10, 0.4 mm in the thickness t of each of the third portions 9, 10, and 16 mm in the overall width.

Evaluation Test 1

The welds 41, 30 produced in the semifinished flat tubes 40, 30 of Examples 1 to 9 by laser welding were observed.

These semifinished flat tubes 40, 30 of Examples 1 to 9 were also assembled through the steps preceding the brazing step in fabricating condensers like the one shown in FIG. 15 and were checked for handleability for assembling. Table 1 shows the results.

Table 1

Example	Pitch P (mm)	Evaluation
1	-	A
2	10	A
3	20	A
4	30	A
5	40	B
6	50	B
7	60	B
8	70	C
9	80	C

With reference to Table 1, the column of "Evaluation," "A" indicates that the tube has no cracks in the laser weld, has high rigidity and is reliably insertable into the tube inserting hole of the header in assembling the condenser; "B" indicates that fine cracks, although found in the laser weld, cause no trouble in brazing the two third portions to each other, and that the tube is reliably insertable into the tube hole of the header in assembling the condenser, and "C" indicates that fine cracks, although found in the laser weld, cause no trouble in brazing the two third portions to each other, and that the tube has slightly open ends such that about 2 to 3%

of all the tubes used for assembling the condenser are not insertable into the tube hole of the header.

Examples 10-15

An aluminum brazing sheet made from JIS BAS211P was rolled into a metal plate 15 shown in FIG. 3, (a). The metal plate was then made into a semifinished flat tube 30 wherein two third portions 9, 10 were intermittently joined to each other at a spacing longitudinally thereof by laser welding as shown in FIGS. 4 to 6. The laser welding conditions were: pulse width, 0.5 ms; frequency, 66.7 Hz; pulse energy, 3 J; assist gas, none; work moving velocity, 200 m/min. The laser weld 31 positioned at each of opposite end portions of the third portions 9, 10 was at a distance L of 15 mm from the longitudinal end of the third portion. The pitch P of all the welds was 30 mm. The tubes 30 of the examples were produced with varying values for D/H and for d/t wherein D is the nugget diameter of laser the welds 31, H is the combined height of the two third portions 9, 10, d is the depth of penetration of the laser welds 31, and t is the thickness of each of the third portions 9, 10. These semifinished flat tubes 30 were 1.1 mm in the combined height H of the two third portions 9, 10, 0.4 mm in the thickness t of each of the third portions 9, 10, and 16 mm in the overall width.

Evaluation Test 2

The welds 30 produced in the semifinished flat tubes 30 of Examples 10 to 15 by laser welding were observed. Table 2 shows the results.

Table 2

Example	Results of observation of laser welds				
	D/H	d/t			
		0.25	0.5	0.75	1
10	0.18	Y	Y	Y	
11	0.27	Y	X		X
12	0.36	Y		X	
13	0.45	Y	X	X	
14	0.55	X	X	X	X
15	0.64	X	X	X	

With reference to Table 2, the columns of "Results of observation of laser welds," "X" indicates that no cracks are found in the laser welds, and "Y" indicates that fine cracks, although found, cause no trouble in brazing the two third portions to each other.

Tables 1 and 2 reveal that the laser welds in the semifinished flat tubes of the present invention develop no cracks that would produce faults in the subsequent step of brazing, further indicating that the tubes are highly handleable in assembling the condenser.

FIG. 8 shows another embodiment of flat tube.

With reference to FIG. 8, a flat tube 50 has a left side wall 4, which is formed by downwardly folding over the left side edge of an upper wall 2 to form a portion 51, folding back the left side edge of a lower wall 3 to form a portion 52 and brazing the two portions 51, 52 to each other in a butting

relation.

Each of reinforcing walls 6 is formed by bending the upper wall 2 downward to form a downward ridge 53, brazing the lower edge of the ridge 53 to the lower wall 3, bending the lower
5 wall 3 upward to form an upward ridge 54 and brazing the upper edge of the ridge 54 to the upper wall 2. The downward edges 53 and the upward edges 54 are arranged alternately leftward or rightward.

The flat tube 50 is produced by making a semifinished
10 flat tube first, and brazing the required portions of the tube.

The semifinished flat tube is produced in the manner shown in FIG. 9.

Prepared first from an aluminum brazing sheet clad with a brazing material over opposite surfaces is a metal plate
15 55 as shown in FIG. 9, (a) for use in producing the semifinished flat tube. The metal plate 55 comprises two flat first portions 56, 57 for making the upper and lower walls 2, 3, and a second portion 58 connecting the two first portions 56, 57 to each other integrally for making a right side wall 5. The first
20 portions 56, 57 have upwardly projecting bent portions 59, 60 extending longitudinally of the metal plate 55 and arranged at a spacing leftward or rightward. Each bent portion 59 (60) comprises a vertical upright part 59a (60a) which is perpendicular or substantially perpendicular to the metal plate
25 55, and a slanting upright part 59b (60b) which is inclined at predetermined angles with respect to the metal plate 55 and the vertical upright part 59a (60a). There is a clearance between the two upright parts 59a, 59b (60a, 60b). The bent

portions 59 of the first portion 51 for making the upper wall 2 and the bent portions 60 of the other first portion 52 for making the lower wall 3 are positioned asymmetrically about the widthwise center line of the metal plate 55.

5 The metal plate 55 is then contracted in the widthwise direction, whereby the upright portions 59a, 59b (60a, 60b) of each bent portion 59 (60) are brought into intimate contact with each other to make the upwardly projecting ridge 53 (54). The first portions 56, 57 are bent upward each at a side edge
10 portion thereof opposite to the second portion 58, whereby upwardly projecting third portions 51, 52 are formed for making the left side wall 4 [see FIG. 9, (b)].

 The metal plate 55 is then wound into a coil with the third portions 51, 52 and the ridges 53, 54 facing radially
15 inward, and the coil is placed on the supply roll 21 of the production apparatus shown in FIG. 2 to produce a semifinished flat tube using the apparatus.

 Stated more specifically, the metal plate 55 paid out from the coil on the supply roll 21 is treated by the
20 straightening device 22 for the removal of distortion, and thereafter fed to the roll forming device 23, by which the metal plate 55 is progressively bent at opposite side edges of the second portion 58 by the roll forming process [see FIG. 9, (c)] and finally bent into the shape of a hairpin to
25 cause the two third portions 51, 52 to butt against each other, to contact the ridges 53 of the first portion 56 with the other first portion 57, and to contact the ridges 54 of the other first portion 57 with the first portion 56, whereby a bent

body 61 is obtained [see FIG. 9, (d)]. At this time, the right side wall 5 is formed by the second portion 58, the upper wall 2 by the first portion 56 and the lower wall 3 by the other first portion 57.

5 The bent body 61 is then fed to the laser welding device 25, by which the butting parts of the two third portions 51, 52 are joined by laser welding intermittently at a spacing along the length thereof from outside to make a semifinished continuous body. Subsequently, the semifinished continuous
10 body has its distortion corrected by the straightening device 26 and is thereafter cut into semifinished flat tubes each having two laser welds respectively at longitudinal opposite end portions of the third portions 51, 52. FIG. 10 shows the semifinished flat tube 65 thus produced.

15 As shown in FIG. 10, the semifinished flat tube 65 is obtained by intermittently welding the two third portions 51, 52 to each other at the butting ends thereof at a spacing longitudinally of these portions by laser welding, and has a plurality of welds 66 formed at a spacing along the
20 longitudinal direction. The semifinished flat tube 65 is the same as the semifinished flat tube shown in FIGS. 4 to 6 with respect to the distance L of the laser weld 66 and positioned at each of opposite end portions from the longitudinal end of the third portion 51 or 52, the pitch P of all the laser
25 welds 66, the relationship D/H between the nugget diameter D of the laser welds 66 and the combined height H of the third portions 51, 52, and the relationship d/t between the depth of penetration d of the laser welds 66 and the thickness t

of each of the third portions 51, 52.

To produce a flat tube from the semifinished flat tube 65, the tube 65 is heated at a predetermined temperature to braze the two third portions 51, 52 to each other, the ridges 53 of the first portion 56 to the other first portion 57, and the ridges 54 of the other first portion 57 to the first portion 56, utilizing the brazing material layer on the metal plate 55, whereby the left side wall 4 and each reinforcing wall 6 are formed. Thus, the flat tube 50 is produced.

When the flat tube 50 is to be used, for example, as the refrigerant tube 102 of the condenser shown in FIG. 15, such flat tubes 50 may be produced by the foregoing process simultaneously with the fabrication of the condenser as in the case where flat tubes 1 are used.

FIG. 11 shows another embodiment of semifinished flat tube for use in producing the flat tube 50 of FIG. 8.

FIG. 11 shows a semifinished flat tube 70 having two third portions 51, 52 which are joined to each other continuously by laser welding over the entire length thereof. The semifinished flat tube 70 is the same as the semifinished flat tube 65 shown in FIG. 10 with respect to the relationship W/H between the width W of the continuous laser weld 71 formed by laser welding and the combined height H of the third portions 51, 52, and the relationship d/t between the depth of penetration d of the laser weld 71 and the thickness t of each of the third portions 51, 52.

Using the apparatus shown in FIG. 2, the semifinished flat tube 70 is produced by the same process as the semifinished

flat tube 65 shown in FIG. 10, whereas the process differs from the process for the tube 65 in that the welding operation to be conducted by the laser welding device 25 is performed continuously to join the two third portions 51, 52 over the entire length thereof from outside.

The heat exchanger comprising flat tubes 50 which are produced from semifinished flat tubes of either one of the two types 65, 70 described is used in vehicles comprising a refrigeration cycle having a compressor, a condenser and an evaporator, as the condenser of the refrigeration cycle. Alternatively, the heat exchanger is used as the evaporator of the refrigeration cycle. Further alternatively, the heat exchanger may be installed in motor vehicles to serve as an oil cooler or radiator.

FIG. 12 shows still another embodiment of flat tube.

With reference to FIG. 12, a flat tube 80 has an upper wall 2 comprising left and right two portions 81, 82, and left and right opposite side walls 4, 5 integral with the upper and lower walls 2, 3. A reinforcing wall 6 is provided by bending the two portions 81, 82 of the upper wall 2 vertically downward each at a side edge portion opposite to the side wall 4 or 5 to form portions 83, 84, brazing the lower edges of the portions 83, 84 to the lower wall 3 in contact therewith, and brazing the portions 81, 82 to each other and the portions 83, 84 to each other.

The flat tube 80 is produced by making a semifinished flat tube first, and brazing the required portions of the tube.

The semifinished flat tube is produced in the manner shown

in FIG. 13.

Prepared first from an aluminum brazing sheet clad with a brazing material over opposite surfaces is a metal plate 85 as shown in FIG. 13, (a) for use in producing the semifinished flat tube. The metal plate 85 comprises a first portion 86 for making the lower wall 3, two second portions 81, 82 having an approximately one-half the width of the first portion 86 for making the upper wall 2, two third portions 87, 88 connecting the first portion 86 to the respective two second portions 81, 82 for making the left and right side walls 4, 5, and two fourth portions 83, 84 extending upright from the respective second portions 81, 82 and each formed on the second portion 81 or 82 at a side edge thereof opposite to the third portion 87 or 88.

Subsequently, the metal plate 85 are bent at the two third portions 87, 88 [see FIG. 13, (b) and (c)] to cause the side edges of the second portions 81, 82 where the fourth portions 83, 84 are formed to butt against each other, to bring the fourth portions 83, 84 into intimate contact with each other and to bring the lower ends of the fourth portions 83, 84 into contact with the first portion 86, whereby a bent body 89 is obtained [see FIG. 13, (d)].

The butting portions of two second portions 81, 82 of the bent body 89 are thereafter joined to each other intermittently at a spacing longitudinally thereof by laser welding from outside to make a semifinished continuous body.

Subsequently, the continuous body is cut into semifinished flat tubes so that two welds are positioned at longitudinal

opposite end portions of the second portions 81, 82. In this way, the semifinished flat tube 90 shown in FIG. 14 is produced.

The semifinished flat tube thus obtained is the same as the semifinished flat tube shown in FIGS. 4 to 6 with respect
5 to the distance L of the laser welds 91 positioned at opposite end portions from the respective longitudinal ends of the second portions 81, 82, and the pitch P of all laser welds 91.

Incidentally with the semifinished flat tube shown in FIG. 14, the two second portions 81, 82 may be joined to each
10 other continuously over the entire length thereof by laser welding instead of intermittently welding the second portions 81, 82.

A flat tube 80 is produced from the semifinished flat tube 90 by heating the tube 90 at a predetermined temperature
15 to braze the lower edges of the fourth portions 83, 84 to the first portion 86 utilizing the brazing material layer of the metal plate 85 and to braze the two second portions 81, 82 to each other and the two fourth portions 83, 84 to each other utilizing the brazing material layer on the metal plate 85,
20 whereby the upper wall 2 and the reinforcing wall 6 are formed. Thus, the flat tube 80 is produced.

A heat exchanger comprising such flat tubes 80 is used in vehicles, such as motor vehicles, as a heater core.

25 INDUSTRIAL APPLICABILITY

The semifinished flat tubes are suitable for producing flat tubes for use as heat exchange tubes for heat exchangers, such as refrigerant tubes in condensers or evaporators for

motor vehicle air conditioners, oil tubes for motor vehicle oil coolers, water tubes for motor vehicle radiators and heat medium tubes for heater cores.